High Gain Inverted-F and Loaded Inverted-F Antennas for WLAN/Wi-Fi Applications

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***Abstract*—This paper represents the numerical simulations of high gain inverted-F and loaded inverted-F antennas (IFA) for WLAN/Wi-Fi applications. The dimensions of the antennas are 16×34, 21×34 and 26×34 mm^2 in case of IFA, slightly loaded IFA (SLIFA) and heavily loaded IFA (HLIFA) respectively. The antennas contain a very good peak gain of 7.89, 8.11 and 8.15 dBi with less than 1.2, 1.0 and 0.8 dBi gain variation within the -10 dB return loss bandwidth for IFA, SLIFA and HLIFA respectively. Moreover the proposed antennas can provide more than the required bandwidths for WLAN/Wi-Fi operations at 2.4 GHz (2.4~2.484 GHz) band. In addition, the proposed antennas have achievable return loss and radiation characteristics. Due to the compactness of the antennas, they are promising to be embedded within the different portable devices employing WLAN/Wi-Fi applications.**

***Index Terms*— Inverted-F antenna (IFA), SLIFA, HLIFA, WLAN, Wi-Fi.**

I. Introduction

Commercial wireless communication applications increasing very rapidly at the recent time and microstrip antennas play a vital role in the development of these fast growing communication systems. At present the demand of Wireless local area networks (WLANs) are increasing numerously worldwide, since they provide high speed connectivity and easy access to networks without requiring wiring also in recent times Wireless Fidelity (Wi-Fi)-enabled wireless devices such as the laptop, personal computer, mobile phone, etc, are becoming popular in a greater extent. Most of the current WLAN and Wi-Fi enabled products being deployed are based on the IEEE 802.11b standard operating at 2.4 GHz (frequency ranges 2.4~2.484 GHz) band [1]-[5]. The Bluetooth operating frequency band is generally defined as the band from 2.4–2.485 GHz and working band of RFID technology has cover 100~500 KHz in the low band range, 13.56 MHz in the high band and microwave band range including 860~960 MHz and 2.45 GHz [6],[7]. A low profile antenna which has high gain, achievable bandwidth, excellent omnidirectional radiation pattern, and which is cost- effective, and can be directly mounted on the system circuit board or the ground plane of the mobile device is extremely preferred for short range wireless communication [8]-[10]. For this reason miniaturized antenna with suitable gain and satisfactory bandwidth for WLAN/Wi-Fi applications are extremelyenviable.

A printed multiband antenna on the printed circuit board (PCB) with a peak gain at resonant frequency of 2.4 GHz is -2.06 dBi on the azimuth (H-plane) and - 3.1dBi on the elevation (E-plane) respectively [1]. Although the antenna can support multiband operations and bandwidth is wide but the gain negative at 2.4 GHz band. Monopole slot antenna printed on a small 0.8-mm thick FR4 substrate of length 15 mm and width 6 mm has a gain about 3.0 – 3.4 dBi over the 2.4 GHz WLAN band [2]. Though the antenna can operate for WLAN/WiMAX its gain is low. On the other hand inverted-F antenna printed on a PCMCIA card has the gain of 2.50 dBi at 2.45 GHz and the antenna has quasi-omnidirectional pattern in xy plane [4]. A chip antenna mounted above the system ground plane of a mobile device with a gain of less than 3.5 dBi is proposed for the 2.4 GHz ISM band [5]. The printed integrated inverted-F antenna has a free-space peak gain of 1.5 dBi [6]. A dipole antenna with rectangular fractal shape radiator element has a gain of 3.3 to 5.7 dBi within microwave operation frequency [7]. For this case the antenna size is very big and the gain variation is large. Performing the antenna miniaturization the researchers have been proposed compact micro-strip antenna based on shorting pin technique provides gain of 0 dBi [8]. Compact monopole antenna printed on an FR4 substrate (with a relative permittivity of 4.2 and a thickness of 1.6 mm) for dual band operation has a maximum gain of 1.354 dBi at 2.4 GHz band [9]. A small-size microstrip-coupled printed PIFA suitable for WLAN operation in the 2.4 and 5.2/5.8 GHz bands has a gain of 3 dBi over the 2.4 GHz band [10]. Printed monopole antenna can provide the wider bandwidth and multiband operation with gain less than 2 dBi over the 2.4 GHz band [11]. However a micro-strip coupled printed inverted-F antenna has wider bandwidth but the gain is not over 2dBi [12]. The micro-strip line fed half-cylindrical dielectric resonator antenna (DRA) has a peak gain of 5.5 dBi in the elevation plane and 3.5 dBi in the azimuth plane [13]. The monopole antenna fed by a coplanar waveguide built on a FR4 substrate support two operating band but the gain at 2.4, 2.45 and 2.5 GHz frequency is 1, 1.6 and 1.4 dBi respectively [14].

To provide the increasing demand and cover up the widespread applications of WLAN and Wi-Fi, an antenna with high gain, satisfactory bandwidth and less gain variation within the antenna bandwidth is desired. To meet up most of mentioned requirements, Inverted-F antenna is one of the good candidates within the micro-strip printed antennas.

II. Antenna Design

The geometry of the proposed antennas for achieving intense performance for WLAN or Wi-Fi applications are

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shown in Figs. 1, 2 and 3. Using method of moments (MoM's) in Numerical Electromagnetic Code (NEC) [15], we conducted parameter studies to ascertain the effect of different loading on the antenna performance to find out the optimal design and the optimized dimensions of the antennas are given in Table I. The cost of FR4 substrate is higher than the RT/duroid 5880. For the lower cost, in numerical analysis we considered the substrate permittivity of the antenna is ε_r = 2.2 (RT/duroid 5880) with substrate thickness 0.127 mm.

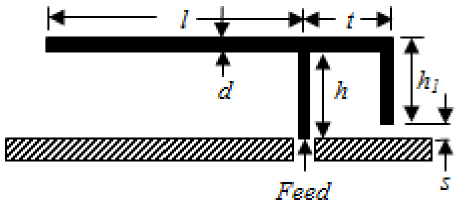

Figure 1. Inverted-F Antenna (IFA)

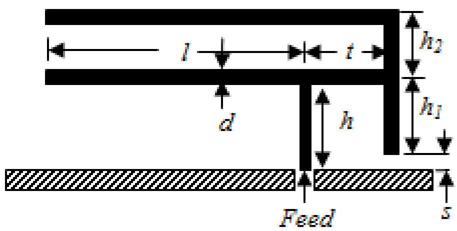

Figure 2. Slightly loaded inverted-F antenna (SLIFA)

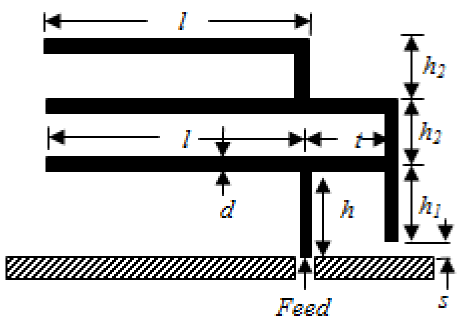

Figure 3. Heavily loaded inverted-F antenna (HLIFA)

Our attempt was to improve the gain, reduce the gain variation and improving the radiation pattern in horizontal and vertical plane for operation of WLAN/Wi-Fi applications. However if we modify the inverted-F antenna by applying a suitable structured load of length *(l+t)* on the horizontal branch of the IFA then the antenna named as slightly loaded inverted-F antenna (SLIFA) as shown in Fig. 2 and further adding another branch on SLIFA of length *l* then the antenna named as heavily loaded inverted-F antenna (HLIFA) as shown in the Fig. 3.

The antennas are assumed to feed by a 50 Ω coaxial cable, with its central conductor connected to the feeding point and its outer conductor connected to the ground plane. In the analysis, the dimensions of the ground plane considered as 60 mm × 60 mm.

TABLE I.
DIMENSIONS OF THE PROPOSED ANTENNAS

Antenna Name	Antenna Parameters	Values (mm)	Dimension (mm^2)
IFA	*l*	28	16×34
	t	6	
	h	16	
	h_1	15.6	
	d	2	
	s	0.4	
SLIFA	*l*	28	21×34
	t	6	
	h	16	
	h_1	15.6	
	h_2	5	
	d	2	
	s	0.4	
HLIFA	*l*	28	26×34
	t	6	
	h	16	
	h_1	15.6	
	h_2	5	
	d	2	
	s	0.4	

III. Numerical Simulations Result

The proposed antennas are constructed and numerically analyzed using method of moments. The numerical results of the antennas are shown below. The proposed antennas have the return loss appreciable than the commonly required return loss -10 dB level. By applying a suitable load to the inverted-F antenna, the antenna gain and gain variation improves appreciably. The numerical analysis of the proposed structures such as inverted-F, slightly loaded inverted-F and heavily loaded inverted-F antennas to realize the operation for WLAN/Wi-Fi are presented below.

The IFA has the VSWR (Voltage Standing Wave Ratio) 1.8140, 1.2997, and 1.689 at 2.4, 2.45 and 2.485 GHz respectively with bandwidth of 150 MHz (from 2390-2540 MHz). The SLIFA has the VSWR (Voltage Standing Wave Ratio) 1.789, 1.3594, and 1.166 at 2.4, 2.45 and 2.485 GHz respectively with bandwidth of 190 MHz (from 2390-2580 MHz), and the HLIFA has the VSWR (Voltage Standing Wave Ratio) 1.7087, 1.2998, and 1.1355 at 2.4, 2.45 and 2.485 GHz respectively with bandwidth of 140 MHz (from 2380-2520 MHz) as shown in Figs. 4 (a) and (b). Fig. 5 (a) represents the total gain of IFA, SLIFA and HLIFA. The peak gain of IFA, SLIFA and HLIFA are 7.89, 8.11 and 8.15 dBi and the gain variation within the -10 dB return loss bandwidth is less than 1.2, 1.0 and 0.8 dBi respectively, which indicates the antenna has stable gain within the antenna bandwidth. Due to the application of the suitable load on the inverted-F antenna the antenna gain improves as well as gain variation decreases significantly. Fig. 5 (b) shows the antennas input impedance variation with frequency. For better impedance matching with the 50 &! micro-strip line or coaxial connector the antenna input impedance should be near about 50 Ω. The input impedance of the proposed antennas are near about 50 Ω at the 2.4 GHz frequency bands, so extra impedance matching network is

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not essential for the operation of the antennas.

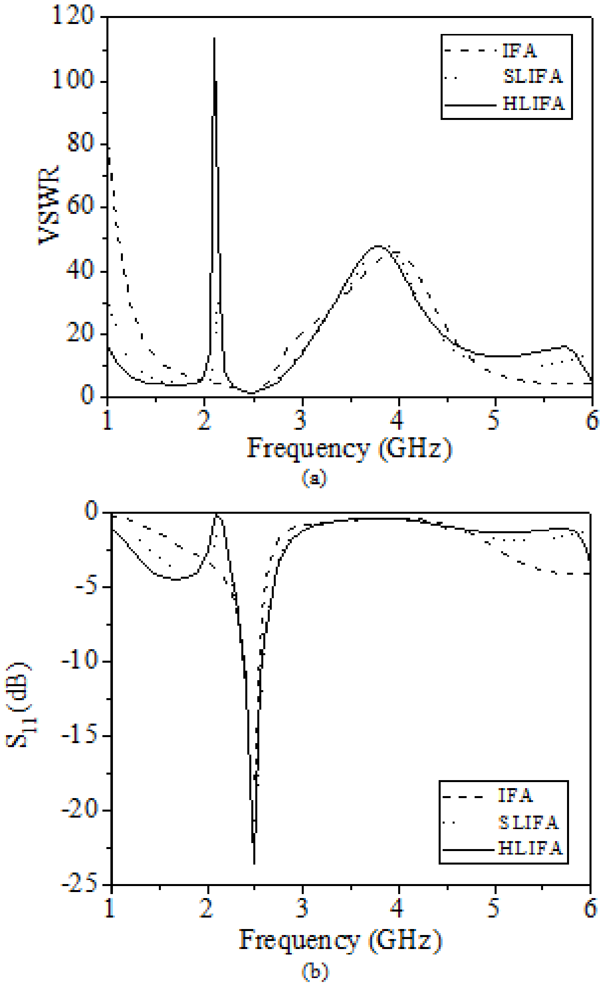
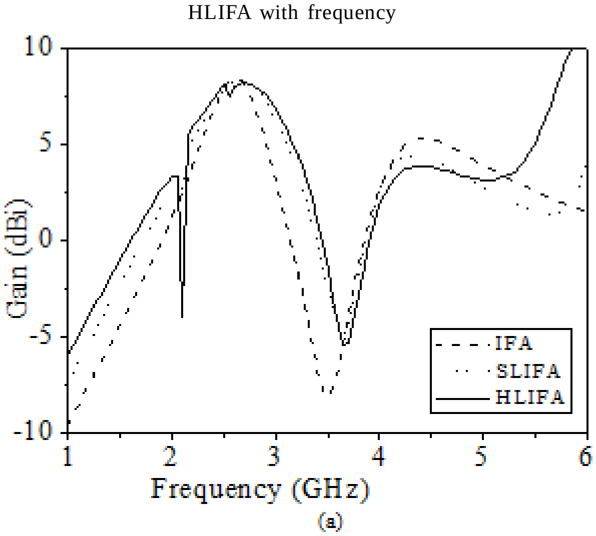


Figure 4. (a) VSWR variation (b) Return loss of IFA, SLIFA and HLIFA with frequency



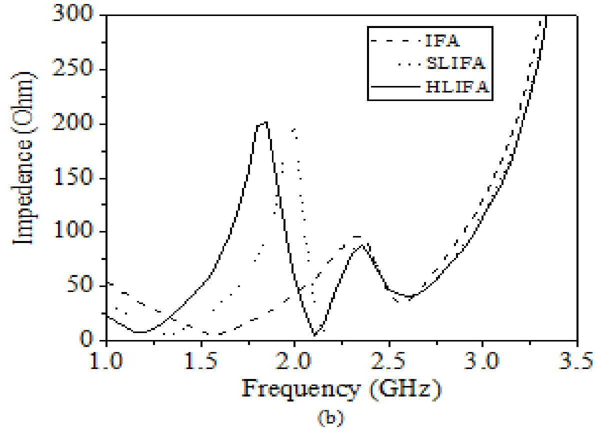


Figure 5. (a) Total gain (b) Impedance variation of IFA, SLIFA and HLIFA with frequency

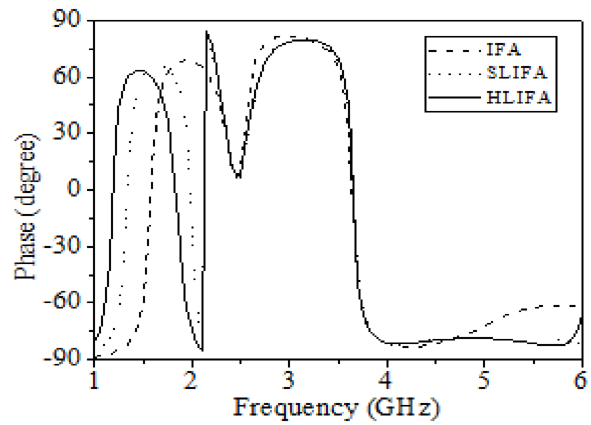
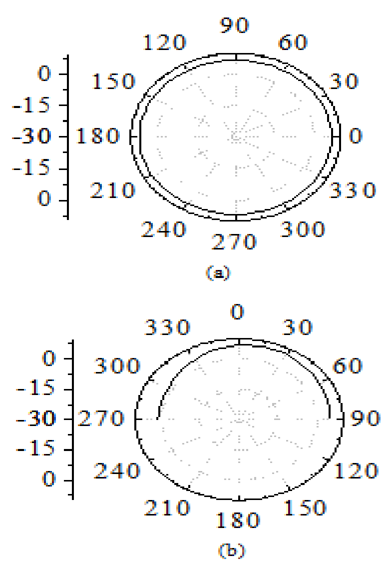


Figure 6. Phase variation of IFA, SLIFA and HLIFA with frequency

Fig. 6 represents the antenna phase shift causes due to the impedance mismatch as a function of frequency. The phase shift of IFA, SLIFA and HLIFA are 6.74051^0, 6.92694^0 and 7.62397^0 at 2.45 GHz indicate that the phase shift of all antennas is closer to 0^0. Figs. 7 to 9 show the radiation patterns of IFA, SLIFA and HLIFA. The antennas total radiation in vertical and horizontal plane is fully omnidirectional which is desired for the WLAN/Wi-Fi applications.



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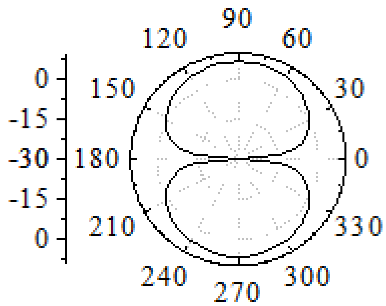

(c)

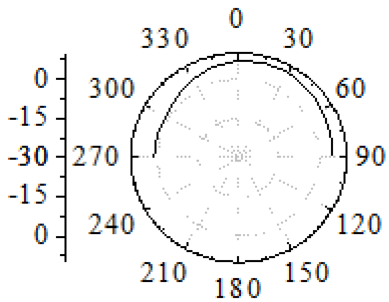

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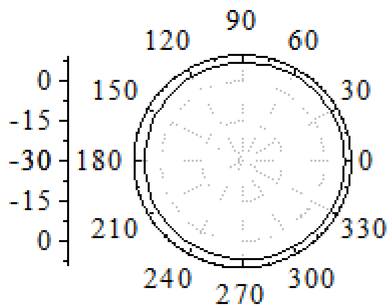
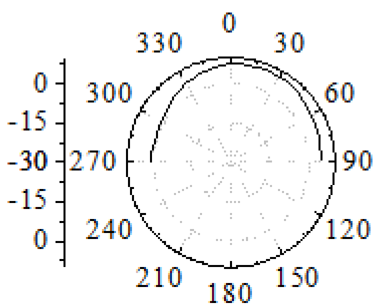
Figure 7. (a) Total gain pattern in horizontal plane (b) Total gain pattern in vertical plane (c) Horizontal gain pattern in horizontal plane (d) Vertical gain pattern in vertical plane of IFA at 2.4 GHz



(a)



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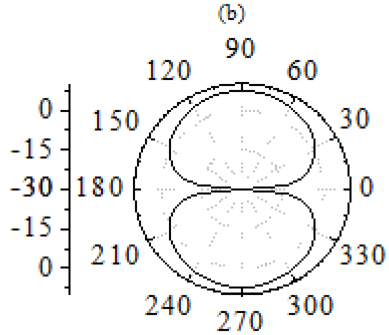

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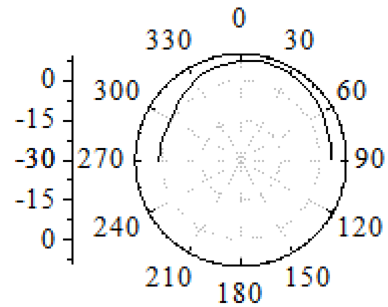
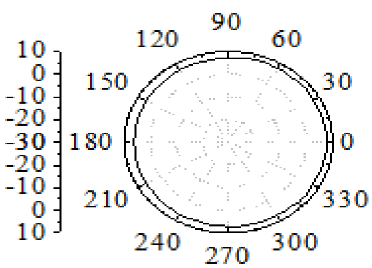
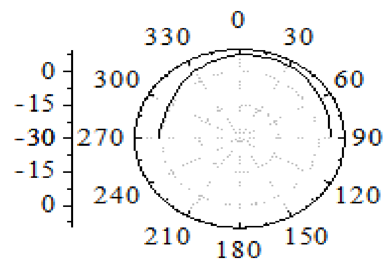


(d)

Figure 8. (a) Total gain pattern in horizontal plane (b) Total gain pattern in vertical plane (c) Horizontal gain pattern in horizontal plane (d) Vertical gain pattern in vertical plane of SLIFA at 2.4 GHz



(a)



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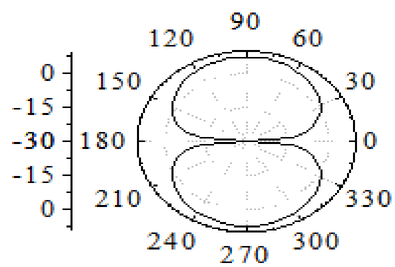

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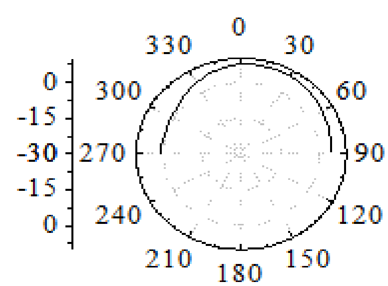

(d)

Figure 9. (a) Total gain pattern in horizontal plane (b) Total gain pattern in vertical plane (c) Horizontal gain pattern in horizontal plane (d) Vertical gain pattern in vertical plane of HLIFA at 2.4 GHz

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A printed multiband antenna on the printed circuit board (PCB), monopole slot antenna printed on a small 0.8 mm thick FR4 substrate, inverted-F antenna printed on a PCMCIA card, chip antenna mounted above the system ground plane of a mobile device, the printed integrated inverted-F antenna, dipole antenna with rectangular fractal shape radiator element, compact micro-strip antenna based on shorting pin technique, compact monopole antenna printed on an FR4 substrate, small-size microstrip-coupled printed PIFA, printed monopole antenna, micro-strip coupled printed inverted-F antenna, micro-strip line fed half-cylindrical dielectric resonator antenna (DRA), monopole antenna fed by a coplanar waveguide built on a FR4 substrate suffer from the gain limitations for the WLAN/Wi-Fi operation at 2.4 GHz band [1-14]. But the gains of the proposed antennas are much improved with stable gain variation within the antenna bandwidth then the antennas proposed previous.

Conclusions

A simple structured inverted-F, slightly loaded inverted-F, and heavily loaded inverted-F antennas for WLAN/Wi-Fi application is proposed by means of numerical simulations. The antennas occupy a small area of 16×34 mm^2, 21×34 mm^2 and 26×34 mm^2 for inverted-F, slightly loaded inverted-F, and heavily loaded inverted-F antenna with peak gain of 7.89, 8.11 and 8.15 dBi and bandwidth of 150, 190 and 140 MHz respectively. Moreover the gain variation of the antennas at the required band is very low. The simulated patterns, return loss, and radiation impedance are desirable for the WLAN/Wi-Fi applications.

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